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16. Summary/Notes

One non-supervised and three supervised classifiers of the Image-100 system were used to compare wheat classification accuracy in Cruz Alta, Rio Grande do Sul State. The significant results obtained from this study are:

- *A better indication of correct classification can be provided by using a test area which contains various cover types of the study area.*
- *Classification accuracy should be evaluated considering both the percentages of correct classification and error of commission.*
- *Supervised classification approaches are better than K-means clustering.*
- *Gaussian distribution maximum-likelihood classifier is better than Single-cell and Multi-cell Signature Acquisition Options of the Image-100 system.*
- *In order to obtain a high classification accuracy in a large and heterogeneous crop area, using Gaussian maximum-likelihood classifier, homogeneous spectral subclasses of the study crop should be created to derive training statistics.*

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COMPARISON OF WHEAT CLASSIFICATION ACCURACY USING DIFFERENT CLASSIFIERS OF THE IMAGE-100 SYSTEM

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ABSTRACT

This paper compared wheat classification results using Single-cell and Multi-cell Signature Acquisition Options, a point-by-point Gaussian maximum-likelihood classifier, and K-means clustering of the Image-100 system. Each classifier was used to distinguish wheat from non-wheat in Cruz Alta, Rio Grande do Sul State, Brazil. Independent training and test areas (each area $\approx$ 20 pixels) were used in classification procedures. In order to give a more realistic view of the classification performance, a test area of approximately 40 km^2, with a variety of land cover types, was also selected. The rescaled alphanumeric theme print of each classifier was overlaid on IR aerial photographs. A point-by-point comparison of the theme print to its corresponding aerial photographs, provided the percentages of correct classification and error of commission. The study results show that using small test areas of one cover type to evaluate classification performance may lead to an optimistically high percent correct classification. In addition, percent

correct classification should not be the only factor used for evaluation. The error of commission plays an important role in the estimate of area, which is generally the main objective for crop inventory study. Among the examined classifiers, the point-by-point Gaussian maximum-likelihood classifier, using four spectral subclasses of wheat, shows the best performance. This classifier gave an 87.3% correct classification, a 12.9% commission error, and an overestimate of 0.[illegible]% in wheat area when compared to that obtained from aerial photographs.

INTRODUCTION

For correct crop identification using LANDSAT multispectral scanner data and computer-aided analysis, the distinguishable spectral response of this crop type has to be defined. There are several classifiers,based on different classification criteria, available in the Image-100 system of the Brazilian Institute for Space Research (INPE). All these classifiers can be used to derive statistics of the spectral responses for study classes. Thus, one of the problems commonly encountered by a remote sensing data analyst is to decide which classifier is the best to use. In order to obtain an accurate crop area estimate, the selected classifier should provide not only the maximum correct classification but also the minimum error of commission.

In this study, classification performances on wheat of one unsupervised and three supervised classifiers of the Image-100 system*, were compared. Based on the study results, the optimal classifier will be selected for an on-going crop forecasting project. Due to time constraints, in this study qualitative comparison of classification results was made on the whole study area ($\approx$ 400 km^2), while detailed quantitative analysis of point-by-point comparison was carried out in an intensive test area of 40 km^2.

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* Image-100 is an interactive image analyser marketed by General Electric Co. to analyze MSS data.

STUDY AREA AND DATA ACQUISITION

Cruz Alta is one of the major municipals for wheat production in Rio Grande do Sul State, Brazil. The geographic location of this municipal is around 28°35'S and 53°45'W. An area in Cruz Alta of approximately 400 km², which represents the wheat plantation of the state, was selected as study area (Fig. 1). In this region, depending on climatic conditions, wheat may be planted in April or May and be harvested in October and November. For the crop year 1979, the wheat planting area in April decreases 60% in comparison to the same period of 1978. This decrease is attributed to a dry spell in April and some changes in the financial system which made farmers reluctant to plant. Intensive planting was only initiated in late May when these financial changes were lifted and a 100% loan was available to farmers (1). Wheat calendar, with a planting season in late May, is presented in Fig. II.

a) Aircraft Data Acquisition

On September 4, 1979, a cloud-free day, INPE's aircraft Bandeirante was flown over the study area and color infrared (CIR) aerial photographs of medium scale (1:20,000) were taken using RC-10 photogrammetric camera. These aerial photographs were visually interpreted and served as reference data for wheat classification using LANDSAT data and Image-100 system.

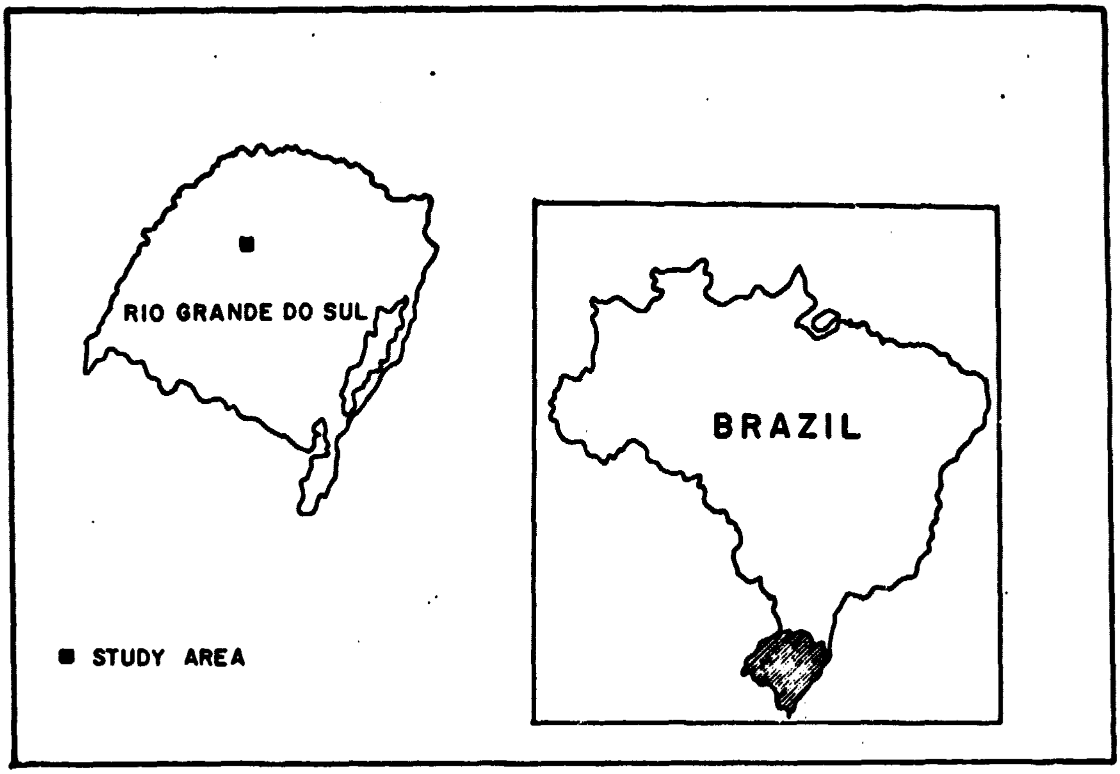

Fig. 1 - Map showing the study area in Cruz Alta, Rio Grande do Sul State.

STAGE \ MONTH	MAY	JUN	JUL	AUG	SEP	OCT	NOV
PLANTING							
EMERGENCE							
JOINTING							
HEADING							
FLOWERING							
SOFT DOUGH							
HARVESTING							

Fig. 2 - Crop calendar of wheat for Rio Grande do Sul State (1979).

b) LANDSAT Data Acquisition

For the crop year 1979, LANDSAT data acquisition at the end of September or in the beginning of October would be the ideal pass for wheat discrimination. This is due to the fact that in September/October, wheat had matured and turned to a golden-yellow color which was significantly different from the surrounding crops (predominantly pasture) that were still green. However, the 100% cloud cover of LANDSAT data on September 22nd, prohibited its utilization. LANDSAT digital data acquired on Sept. 4th was substituted and used for this study. The path/row annotation of these digital data is 220/32.

ANALYSIS PROCEDURES

There are various classifiers available for INPE's Image-100 system to perform analysis of remotely sensed data. The classifiers selected for this study were:

1) Single-cell Signature Acquisition Option: This is a supervised classification procedure. Once the training areas for an informational class are selected by the analyst, the limits of spectral responses of these training areas are used to create a four-dimensional rectangular parallelepipe; each side of which corresponds to the range of spectral response in each channel. An unknown pixel (picture element) is classified to this informational class if the spectral responses of four channels fall into the parallelepipe.

2) Multi-cell Signature Acquisition Option: In this mode of operation, the single-cell approximation is subdivided into many smaller cells. Each pixel of the training area may form a cell which occupies a discrete, known region in spectral space. In this study, the threshold was set to zero, *i. e.*, only empty cells were discarded.

3) MAXVER: Is a supervised, point-by-point Gaussian maximum-likelihood classifier implemented at INPE for the Image-100 system. This classifier has the capacity of analyzing 32 classes with a maximum of 160 training areas. Detailed description of this classifier can be found in Velasco *et al's* paper (2).

4) K-means classifier: This is an unsupervised clustering function. In this operation the analyst has little control over the establishment of the decision region. Spectral information of the randomly selected training areas are clustered into several homogeneous spectral classes. These spectral classes must eventually be converted to informational classes by identifying the ground cover which corresponds to each spectral class.

For supervised classification, fourteen wheat fields, three pasture fields and two plowed fields were used as training areas and carefully located on the image monitor using an electronic cursor. In analyses of Single-cell and Multi-cell Options, only the training areas of wheat were required. For MAXVER classification two training methods were used: a) employing all fourteen training areas to form unique training statistics for *one* wheat class; and b) these fourteen training areas of wheat were divided into *four* subclasses according to their tonality differences on CIR aerial photographs, then, training statistics for each subclass of wheat were derived. Generally speaking, spectral response of a crop in a large and heterogeneous area may vary considerably due to the differences in crop variety, phenological stage, soil type, moisture content, agricultural practice, etc. These heterogeneities in spectral responses may not satisfy the assumption of Gaussian distribution required for the maximum-likelihood classifier. These two approaches for obtaining training statistics were used to test the effect of training method on classification accuracy of MAXVER.

Training areas of unsupervised K-means classification were randomly selected and the number"twelve" was assigned as the initial number for clustering. However, results using twelve cluster centers were too complex to associate with informational classes. After several iterations, eight centers were used for analysis. For purpose of comparison, another training method using the same training areas employed in supervised classification were also included for K-means analysis. The classification approach of MAXVER with unique wheat class, MAXVER with four subclasses of wheat, K-means using random training areas, and K-means using the same training areas as in the supervised classifications, are addressed hereinafter as MAXVER-a, MAXVER-b, K-means (a) and K-means (b), respectively in this article. Once statistics were obtained from training areas, the classification accuracy of each classifier was examined on independent test areas (each area with ≈ 20 pixels) which contained pixels of one cover type. This method of using independent sets of one-cover-type areas for training and testing was widely employed to evaluate classification results (3). However, the authors feel that testing a classifier on small areas with one cover type may lead to an optimistically high percentage of correct classification due to the simplicity of the test areas. Thus, in order to give a more realistic view of classification accuracy, an intensive test area of 40 km^2, with various cover types and representing the complexity of the study area, was also classified using each classification approach. For a detailed quantitative analysis, the alphanumeric theme print (1:20,000) of the intensive test area, using each classifier, was overlaid on CIR aerial photographs of the same scale. Boundaries of each cover type were then locally fitted on a printout to correct relief displacement errors using plowed fields as control points. After boundary delineation, the correctly classified points were counted to assess the classifier effect on percent correct classification of wheat, other cover type and overall (wheat and other cover types as a whole). The proportion of other cover types, which was erroneously classified as wheat, was also calculated and designated as commission error. Estimated wheat area, using each classifier and the Image-100 system, was compared to that obtained from aerial photographs. All of these data are presented in tabular form.

After comparisons were made on test sites, the training statistics of each classifier were applied to the whole study area. Classification results of each classifier were displayed on color CRT of Image-100 system in thematic format. Slides of these results were taken and visual comparisons were made to assess classification differences among classifiers.

RESULTS AND DISCUSSION

Among the various classifiers which used the same training areas to classify wheat, Multi-cell Option gave the lowest percentage of correct classification. The unacceptable low correct classification is due to the fact that only a small fraction of wheat pixels were used for training (Table I). This relatively low pixel number caused the unit cells to be sparsely distributed in the four-dimensional spectral space; where many empty cells may actually represent wheat but did not have any pixel in the space. A lot of wheat pixels were thus omitted from identification. The extremely bad performance of Multi-cell Option is excluded from presentation.

Table II shows the correct classification of various classifiers in small test areas of one cover type. As expected, most of the classifiers had an almost perfect performance. Differences among classifiers were only revealed by comparing the point-by-point classification results in the intensive test area. All classifiers, except K-means (b), have good capabilities to identify wheat (Table III). The lowest percentage of correct classification observed in K-means (b) indicates that some wheat spectral responses were not defined by clustering. This is because 192 wheat pixels were insufficient for clustering where a characteristic wheat spectral response with a low pixel frequency may not be used as a center of cluster. Hence, one-fourth of the wheat pixels were not classified as wheat. The classifier effects on correct classification of wheat, other cover types, and overall were evaluated using analysis of variance on the arcsine transformed data of Table III. No statistically significant difference on correct classification among classifiers was found. However, besides correct classification, commission error is also an important factor in evaluation of classification performance. A classifier, with a high percent correct classification for a given study class and a high commission error, may perform as badly as

TABLE I

THE SIZE OF TRAINING AREA USED FOR SUPERVISED CLASSIFICATION APPROACH

COVER TYPE	NO. OF TRAINING FIELDS	PIXEL NO.
WHEAT	14	192
PASTURELAND	3	108
PLOWED AREA	2	24
TOTAL		324

TABLE II

PERCENTAGE OF CORRECT CLASSIFICATION IN ONE-COVER-TYPE TEST AREA FOR SEVERAL CLASSIFIERS

CLASSIFIER	CORRECT CLASSIFICATION %		
	WHEAT	PASTURELAND	PLOWED AREA
SINGLE CELL	98.3	-	-
MAXVER (a)	100.0	100.0	100.0
MAXVER (b)	99.0	100.0	100.0
K-MEANS (a)	85.7	97.2	100.0

TABLE III

POINT-BY-POINT COMPARISON OF CORRECT CLASSIFICATION IN AN INTENSIVE TEST AREA WITH MORE THAN ONE COVER TYPES USING SEVERAL CLASSIFIERS

CLASSIFIER	CORRECT CLASSIFICATION %		
	WHEAT	OTHER	OVERALL
SINGLE-CELL	88.1	81.6	85.0
MAXVER (a)	84.6	82.5	83.6
MAXVER (b)	87.3	85.3	84.5
K-MEANS (a)	88.7	79.4	84.5
K-MEANS (b)	75.3	89.8	81.9

TABLE IV

POINT-BY-POINT COMPARISON OF CLASSIFICATION PERFORMANCE FOR SEVERAL CLASSIFIERS

CLASSIFIER	CLASSIFICATION PERFORMANCE %		
	CORRECT CLASSIFICATION	ERROR OF COMMISSION	RELATIVE [1] DIFFERENCE
SINGLECELL	88.1	15.8	-4.5
MAXVER (a)	84.6	14.8	-0.7
MAXVER (b)	87.3	12.9	+0.2
K-MEANS (a)	88.7	16.0	+5.6
K-MEANS (b)	75.3	10.7	-15.7

[1] Relative difference was obtained by comparing area estimates from Image-100 and aerial photographs. A negative sign indicates under-estimate, while a positive sign indicates over-estimat in wheat area by the Image-100 system.

those classifiers having low percent correct classifications. Table IV summarizes the correct classification, error of commission and the relative difference of wheat area estimates for each classifier. Commission error ranges from 10.7 to 16.0% for all tested classifiers. The amplitude of this error indicates that there is a certain amount of confusion between spectral responses of wheat and pasture. This is because wheat was in heading/flowering stage in September and presented a similar response to some well-established pastureland. MAXVER-b, which gave an 87.3% correct classification, a 12.9% commission error and the smallest relative difference in area estimates (+ 0.2%), seems to be the most proper classifier for wheat area estimate in the test area. Performance of MAXVER-b was also the best in the whole study area (Fig. III) by comparing slides, where a thematic map of each classifier was shown.

The significant results obtained from this study for wheat classification are:

- A better indication of correct classification can be prov'led by using a test area which contains various cover types of the study area.
- Classification accuracy should be evaluated considering both the percentages of correct classification and error of commission. A higher percent correct classification for a given classifier can be obtained by a trade-off with the percent correct classifications of other cover types. Consequently these lowered percentages in other cover types mav lead to a high commission error which is not desirable for area estimate either.
- Supervised classification approaches are better than K-means

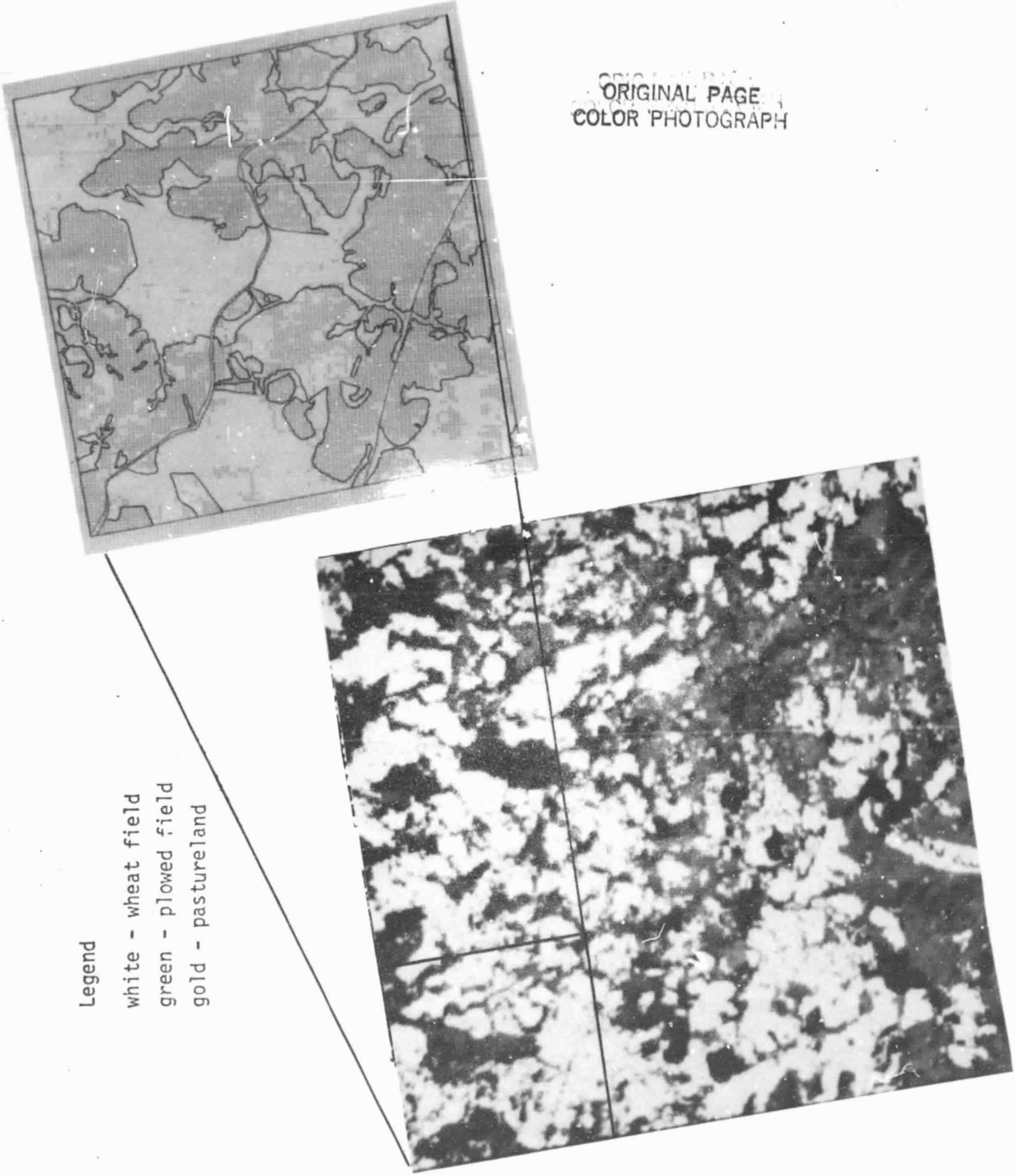

Fig. III - Classification results in the study area using MAXVER-b classifier.

clustering.

- Gaussian distribution maximum-likelihood classifier is better than Single-cell and Multi-cell Signature Acquisition Options of the Image-100 system.
- In order to obtain a high classification accuracy in a large and heterogeneous crop area, using Gaussian maximum-likelihood classifier, homogeneous spectral subclasses of the study crop should be created to derive training statistics.

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